

## PATENT COOPERATION TREATY

REC'D 16 DEC 2004

PCT

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT  
(PCT Article 36 and Rule 70)



3 2005

Applicant's or agent's file reference P32038A/KJO	<b>FOR FURTHER ACTION</b> See Notification of Transmittal of International Preliminary Examination Report (Form PCT/PEA/416)	
International application No. PCT/GB 03/03683	International filing date (day/month/year) 22.08.2003	Priority date (day/month/year) 27.08.2002
International Patent Classification (IPC) or both national classification and IPC H01J49/34		
Applicant THE QUEEN'S UNIVERSITY OF BELFAST et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 6 sheets, including this cover sheet.
- ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 19 sheets.

3. This report contains indications relating to the following items:
- I ☒ Basis of the opinion
  - II ☐ Priority
  - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
  - IV ☐ Lack of unity of invention
  - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
  - VI ☐ Certain documents cited
  - VII ☐ Certain defects in the international application
  - VIII ☐ Certain observations on the international application

Date of submission of the demand  29.03.2004	Date of completion of this report  15.12.2004
Name and mailing address of the international preliminary examining authority:   European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer  Weisser, W  Telephone No. +49 89 2399-2613  

**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT**

International application No.

PCT/GB 03/03683

**I. Basis of the report**

1. With regard to the elements of the international application (*Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17):*

**Description, Pages**

1-29 as originally filed

**Claims, Numbers**

1-96 received on 02.12.2004 with letter of 03.12.2004

**Drawings, Sheets**

1/6-6/6 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT**

International application No. **PCT/GB 03/03683**

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

*(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)*

6. Additional observations, if necessary:

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

**1. Statement**

Novelty (N)	Yes: Claims	11,12,17-20,23-26,30,31,38,59,60,65-68,71-74,78,79,86
	No: Claims	1- 10,13- 16,21, 22,27-29,32-37,39-58,61-64,69,70,75-77,80-85,87-96
Inventive step (IS)	Yes: Claims	11,12,17-20,23-26,30,31,38,59,60,65-68,71-74,78,79,86
	No: Claims	1- 10,13- 16,21, 22,27-29,32-37,39-58,61-64,69,70,75-77,80-85,87-96
Industrial applicability (IA)	Yes: Claims	1-96
	No: Claims	-

**2. Citations and explanations**

**see separate sheet**

1. In this IPER the following documents will be referred to:

D1: US-5206506  
D3: EP-0437085  
D4: WO-98/01012

D3 and D4 are cited by the examiner in accordance with Guidelines Chapter 17.66.  
Copies of the documents are annexed to the communication.

**2. Clarity (Art.6 PCT)**

Present claim 27 seeks to define additional features of the apparatus of claim 1 by defining methods of operating said apparatus (line 6: "in an initial state ... has ..."; line 14: "is applied"; line 20: "is applied") instead of referring to the apparatus per se. It is thereby not clear which features of the claimed apparatus per se are sought implied.

The independent claims is not provided in the two-part form, delimited with respect to the closest prior art as required by Rule 6.3b,ii PCT.

Reference signs are not inserted in the claims to increase their intelligibility (Rule 6.2b PCT).

The most relevant documents are not identified in the description as required by Rule 5.1a,ii PCT.

**3. Novelty (Art.33.2 PCT)**

D1 (cf. e.g. Fig.1,2,4,12a-j,14a,b,17a-d,18) discloses an apparatus for manipulating the phase space of at least one charged particle, comprising at least one electrode (e.g. 12a) arranged on a surface (e.g. the surface of the supporting frame 23 or the spacers 24; cf. Figs.1,2 and col.13, line 20-23) and connected to a power supply (cf. Fig.1) capable of applying both an alternating current voltage and a direct current voltage (cf. e.g. col.17, line 66 - col.18, line 5 and line 41-43; col.23, line 3-56) so as to form a potential which provides a region of phase space manipulation to one side of the electrode surface (cf. e.g. Figs.4, 12a-j, 14a,b, 17a-d, 18), wherein said electrode (12a) does not surround a charge particle whose phase space is manipulated in use.

D1 thereby also discloses a method for manipulating the phase space of at least one charged particle, wherein a combination of alternating current and direct current voltages applied to an electrode (e.g. 12a) forms a potential which provides a region of phase space manipulation, and wherein the at least one charged particle is situated to one side of the electrode surface, wherein said electrode (12a) does not surround a charge particle whose phase space is manipulated in use.

The subject matter of present claims 1 and 49 is therefore not new (Art.33.2 PCT) with regard to D1.

- 3.1 The subject matter of present claims 1 and 49 is also not new (Art.33.2 PCT) with regard to any of D3 (cf. e.g. Fig.1) and D4 (cf. Fig.1).

In D3 an AC (42-46) and DC (plate bias supply 36) voltage is applied to at least one electrode (e.g. plate 22). Said electrode (22) is evidently arranged on a surface (e.g. of a positioning means) and does not surround a charged particle whose phase space is manipulated in use.

D4 (cf. Fig.1) discloses a plasma etch reactor. Both an AC voltage (30, 32) and a DC voltage (34) is applied to an electrode (28) arranged on a surface (of holder 53). The corresponding potential provides a region of phase space manipulation within the reaction chamber. Said electrode (28) does not surround a charged particle whose phase space is manipulated in use.

- 3.2 The subject matter of present dependent claims 2-10, 13-16, 21, 22, 27-29, 32-37, 39-48, 50-58, 61-64, 69, 70, 75-77, 80-85, 87-96 appears also not to be new with regard to D1, D3 and D4 for the following reasons:

- Claims 2,3,50,51: cf. e.g. D1, Fig.2 and col.13, line 42-64 (differentially pumped ion chamber)
- Claims 4,5,6,52,53,54: cf. e.g. D1, col.15, line 54-56; col.18, line 41-44; col.19, line 4-8
- Claims 7,8,55,56: cf. e.g. D1, Figs.4,9,11,12a-j,14a,b,17a-d,18
- Claims 9,10,57,58: cf. e.g. D1, Figs.1,2
- Claims 13-16, 61-64: cf. D3, Fig.1; waver chuck 52 forms a plane as defined in said claims
- Claims 21,22,27-29,69,70,75,77: cf. D1, col.9, line 30-33; col.21, line 49-21; Fig.12a-j; col.23, line 3-56; col.28, line 13-30; Fig.17a-d

- Claims 32-37,39, 80-85,87: cf. D1, col.10, line 56-col.11, line 6; col.18, line 41-col.19, line 9; col.28, line 13-30; col.29-31
- Claims 40, 88: cf. D1, col.13, line 42-64; col.23, line 58- col.28, line 5
- Claims 41, 89: cf. e.g. D1, Fig.14a,b or 12a-j or 17a-d
- Claims 42,43,45,90,91,93: The voltages applied to the electrodes can be adjusted and modified such to cause the particle movements as defined in said claims (cf. e.g. D1, col.9, line 27-33; col.31, line 15-27)
- Claims 44, 92: cf. citations for claims 40 and 88
- Claims 46-48, 94-96: cf. e.g. D1, Figs.1,2 and col.13, line 54-69

3.3. The subject matter of present claims 11, 12, 17-20, 23-26, 30, 31, 38, 59, 60, 65-68, 71-74, 78, 79 and 86 appears to be new according to Art.33.2 PCT.

#### **4. Inventive activity (Art.33.3 PCT)**

The subject matter of present claims 11, 12, 17-20, 23-26, 30, 31, 38, 59, 60, 65-68, 71-74, 78, 79 and 86 appears to be inventive according to Art.33.3 PCT.

#### **5. Industrial applicability (Art.33.4 PCT)**

The subject matter of present claims 1-96 appears to be industrially applicable (Art.33.4 PCT).

\* \* \* \* \*

1    CLAIMS

2

3    1.    Apparatus for manipulating the phase space of  
4    at least one charged particle, comprising at least  
5    one electrode arranged on a surface and connected to  
6    a power supply capable of applying both an  
7    alternating current voltage and a direct current  
8    voltage so as to form a potential which provides a  
9    region of phase space manipulation to one side of  
10   the electrode surface.

11

12   2.    The apparatus of claim 1, further comprising  
13   pressure control means to control the pressure of  
14   the space surrounding the electrodes.

15

16   3.    The apparatus of claim 2, wherein the pressure  
17   control means comprises a sealable chamber and gas  
18   pump means capable of introducing and extracting  
19   gases from the chamber.

20

21   4.    The apparatus of any of claims 1-3, wherein the  
22   power supply is operable to vary the alternating  
23   current and direct current voltages applied.

24

25   5.    The apparatus of any preceding claim, wherein  
26   the power supply is operable to individually alter  
27   the amplitude, waveform, and frequency of the  
28   alternating current voltage, and is operable to  
29   alter the magnitude of the direct current voltage.

30

31   6.    The apparatus of any preceding claim, wherein  
32   the potential is an effective potential.

1 7. The apparatus of any preceding claim, wherein  
2 the region of phase space manipulation comprises a  
3 particle trapping region, wherein a particle is  
4 constrained in a specific spatial area.  
5

6 8. The apparatus of any preceding claim, wherein  
7 the region of phase space manipulation comprises a  
8 particle guide region, wherein a particle's motion  
9 is restrained by at least one degree of freedom.  
10

11 9. The apparatus of any preceding claim, wherein a  
12 plurality of electrodes are provided.  
13

14 10. The apparatus of claim 9, wherein the  
15 electrodes are arranged in an array such that the at  
16 least one particle is situated to one side of the  
17 array.  
18

19 11. The apparatus of claim 10, wherein the array is  
20 substantially planar.  
21

22 12. The apparatus of claim 10, wherein the array is  
23 hemispherical.  
24

25 13. The apparatus of any of claims 1-8, wherein a  
26 single electrode is provided, and is surrounded by a  
27 plane held at a constant potential.  
28

29 14. The apparatus of claim 13, wherein the  
30 electrode is circular.  
31



1 15. The apparatus of claim 13 or claim 14, wherein  
2 the plane is earthed.

3

4 16. The apparatus of claim 14 or claim 15, wherein  
5 the frequency of alternating current voltage applied  
6 to the circular electrode is of a frequency having a  
7 period that is less than the time taken for light to  
8 pass over the diameter of the circular electrode.

9

10 17. The apparatus of any preceding claim, wherein  
11 the voltages applied to adjacent first and second  
12 sets of electrodes in a planar array can be varied  
13 such that the at least one particle can be moved  
14 from the particle trapping region provided by the  
15 first set of electrodes to the particle trapping  
16 region provided by the second set of electrodes.

17

18 18. The apparatus of claim 17, wherein at least one  
19 particle is moved from a first trapping region  
20 provided by a first set of electrodes to a second  
21 trapping region provided by a second set of  
22 electrodes, wherein the voltages applied to the sets  
23 of electrodes is changed from an initial, to an  
24 intermediate and then to a final configuration, and  
25 wherein;

26 in an initial configuration, a first set of  
27 electrodes is biased to a holding voltage to form a  
28 first particle trapping region to trap at least one  
29 particle therein, and an adjacent second set of  
30 electrodes is biased to zero volts;

31 in an intermediate configuration, both sets of  
32 electrodes are biased to the holding voltage to form

1 a merged particle trapping region that traps the at  
2 least one particle;

3 in a final configuration, the first set of  
4 electrodes is biased to zero volts, and the second  
5 set of electrodes is biased to the holding voltage  
6 to form a second particle trapping region, that  
7 traps the at least one particle.

8  
9 19. The apparatus of claim 18, wherein the process  
10 of moving at least one particle from a first  
11 trapping region provided by a first set of  
12 electrodes to a second trapping region provided by a  
13 second set of electrodes is repeatable to move the  
14 at least one particle along a chosen path on the  
15 planar array.

16  
17 20. The apparatus of claim 19, wherein the planar  
18 array is formed using printed circuit board,  
19 lithographic, or focussed ion beam technology.

20  
21 21. The apparatus of any of claims 1-16, wherein a  
22 series of electrodes are provided, the voltages  
23 applied to which are controllable such that the at  
24 least one particle can be moved from a first  
25 particle trapping region to a second particle  
26 trapping region, wherein the first trapping region  
27 is larger than the second trapping region.

28  
29 22. The apparatus of claim 21, wherein the voltages  
30 applied to the electrodes are controllable such that  
31 the at least one particle can be moved between a  
32 plurality of successively smaller trapping regions.

1

2 23. The apparatus of claim 21 or claim 22, wherein  
3 the series of electrodes comprises a plurality of  
4 concentrically arranged circular electrodes.

5

6 24. The apparatus of any of claims 21-23, wherein,  
7 in an initial state, every electrode has a  
8 combination of alternating current and direct  
9 current voltages applied such that at least one  
10 particle is trapped in a first trapping region;

11 the voltage applied to the outer electrode is  
12 changed such that, in an intermediate state, the at  
13 least one particle is trapped in a first  
14 intermediate trapping region provided by the  
15 remaining inner electrodes; and

16 the voltage applied to the electrode adjacent  
17 to the outer electrode is changed such that in a  
18 final state, the at least one particle is trapped in  
19 a second trapping region provided by the innermost  
20 electrode.

21

22 25. The apparatus of claim 24, wherein, in the  
23 transitions from the initial to intermediate and the  
24 intermediate to final states, the outer and adjacent  
25 electrodes respectively are set to zero volts.

26

27 26. The apparatus of claim 24 or claim 25, wherein  
28 a plurality of electrodes each provide a further  
29 intermediate trapping region, such that, between the  
30 initial state and the final state, the at least one  
31 particle passes through a plurality of intermediate

1 states, being trapped in successively smaller  
2 intermediate trapping regions.

3

4 27. The apparatus of any of claims 21-23, wherein,  
5 in an initial state, an outermost electrode has a  
6 first combination of alternating current and direct  
7 current voltages applied, and a background voltage  
8 is applied to the remaining electrodes such that, in  
9 an initial state, at least one particle is trapped  
10 in a first trapping region;

11 the electrode adjacent to the outer electrode  
12 is set to the first combination of voltages and the  
13 background voltage is applied to the outer electrode  
14 such that, in an intermediate state, the at least  
15 one particle is trapped in a first intermediate  
16 trapping region; and

17 the innermost electrode is set to the first  
18 combination of voltages and the background voltage  
19 is applied to the adjacent electrode such that, in a  
20 final state, the at least one particle is trapped in  
21 a second trapping region.

22

23 28. The apparatus of claim 27, wherein the  
24 background voltage is zero volts.

25

26 29. The apparatus of claim 27 or claim 28, wherein  
27 a plurality of electrodes is provided such that,  
28 between the initial state and the final state, the  
29 at least one particle passes through a plurality of  
30 intermediate states, being trapped in successively  
31 smaller intermediate trapping regions.

32

1 30. The apparatus of any of claims 23-29, wherein  
2 Preferably, the innermost electrode is provided with  
3 an aperture; and

4 when the at least one particle is in the final  
5 state, a voltage is applied to the aperture such  
6 that the at least one particle is urged through the  
7 aperture.  
8

9 31. The apparatus of claim 30, wherein each side of  
10 the aperture is differentially pumped so that a gas  
11 passing through the aperture undergoes a supersonic  
12 expansion, so as to cool the particles that are  
13 urged through the aperture.  
14

15 32. The apparatus of any preceding claim, wherein  
16 the voltages applied to an electrode are such that  
17 one type of charged particle can be distinguished  
18 from another.  
19

20 33. The apparatus of claim 32, wherein different  
21 types of charged particle are trapped at different  
22 distances perpendicularly from the surface of the  
23 electrode.  
24

25 34. The apparatus of claim 33, wherein the distance  
26 is dependent on the charge and/or mass of the  
27 charged particle.  
28

29 35. The apparatus of claim 34, wherein a first type  
30 of charged particle is trapped at a first  
31 perpendicular distance from the electrode, and a  
32 second type of charged particle is trapped at a

1 second perpendicular distance from the electrode,  
2 wherein the mass of the first charged particle is  
3 greater than the mass of the second charged  
4 particle, and the second perpendicular distance is  
5 greater than the first perpendicular distance.  
6

7 36. The apparatus of claim 35, wherein at least one  
8 particle trapped at the second perpendicular  
9 distance is subject to the potential formed by a  
10 voltage sequence applied to a second set of  
11 electrodes.  
12

13 37. The apparatus of claim 36, wherein the voltage  
14 sequence applied to the second set of electrodes is  
15 such as to transport said at least one particle from  
16 one trapping region to another along a predetermined  
17 path.  
18

19 38. The apparatus of claim 36 or claim 37, wherein  
20 the dimensions of the second set of electrodes are  
21 of a much larger scale than the dimensions of the  
22 trap electrode.  
23

24 39. The apparatus of any of claims 32-38, wherein  
25 an aperture is provided on an electrode such that  
26 the type of particle that is closest to the surface  
27 of the electrode can pass through the aperture.  
28

29 40. The apparatus of claim 39, wherein each side of  
30 the aperture is differentially pumped so that a gas  
31 passing through the aperture undergoes a supersonic

1 expansion, so as to cool the particles that are  
2 urged through the aperture.

3

4 41. The apparatus of any preceding claim, wherein  
5 the voltages applied to an electrode can be changed  
6 such that a trapped particle moves in a direction  
7 perpendicular to the plane of the electrode.

8

9 42. The apparatus of claim 41, wherein at least one  
10 trapped particle can be lowered to a region where it  
11 will interact with at least one other particle; and  
12 the particles that result from the interaction  
13 can then be raised up again, together with particles  
14 that have not interacted.

15

16 43. The apparatus of claim 41 or claim 42, wherein  
17 the electrode is formed with an aperture and the  
18 applied voltage can be changed to bring a particle  
19 close to the aperture; and

20 a voltage is applied to the aperture such that  
21 the particle is urged through the aperture.

22

23 44. The apparatus of claim 43, wherein each side of  
24 the aperture is differentially pumped so that a gas  
25 passing through the aperture undergoes a supersonic  
26 expansion, so as to cool the particles that are  
27 urged through the aperture.

28

29 45. The apparatus of any of claims 41-44, wherein  
30 an array of electrodes is provided, the voltages  
31 applied to which trap a first type of particle which  
32 can interact with a second type of particle, to form

1 a reactant particle which falls to the bottom of a  
2 trap and is swept away through an extraction hole.

3

4 46. The apparatus of claim 45, wherein the array of  
5 electrodes further comprises at least one aperture  
6 for the extraction of trapped particles.

7

8 47. The apparatus of claim 46, wherein each  
9 electrode comprises one aperture.

10

11 48. The apparatus of claim 47, wherein the reactant  
12 particle is accelerated through a potential and  
13 detected so that the position of the original first  
14 type of particle can be detected.

15

16 49. A method for manipulating the phase space of at  
17 least one charged particle, wherein a combination of  
18 alternating current and direct current voltages  
19 applied to an electrode forms a potential which  
20 provides a region of phase space manipulation, and  
21 wherein the at least one charged particle is  
22 situated to one side of the electrode surface.

23

24 50. The method of claim 49, further comprising the  
25 step of controlling the pressure of the space  
26 surrounding the electrodes.

27

28 51. The method of claim 50, wherein the pressure  
29 control means comprises a sealable chamber and gas  
30 pump means capable of introducing and extracting  
31 gases from the chamber.

32



1     52. The method of any of claims 49-51, wherein the  
2     power supply is operable to vary the alternating  
3     current and direct current voltages applied.

4

5     53. The method of any of claims 49-52, wherein the  
6     power supply is operable to individually alter the  
7     amplitude, waveform, and frequency of the  
8     alternating current voltage, and is operable to  
9     alter the magnitude of the direct current voltage.

10

11     54. The method of any of claims 49-53, wherein the  
12     potential is an effective potential.

13

14     55. The method of any of claims 49-54, wherein the  
15     region of phase space manipulation comprises a  
16     particle trapping region, wherein a particle is  
17     constrained in a specific spatial area.

18

19     56. The method of any of claims 49-55, wherein the  
20     region of phase space manipulation comprises a  
21     particle guide region, wherein a particle's motion  
22     is restrained by at least one degree of freedom.

23

24     57. The method of any of claims 49-56, wherein a  
25     plurality of electrodes are provided.

26

27     58. The method of claim 57, wherein the electrodes  
28     are arranged in an array such that the at least one  
29     particle is situated to one side of the array.

30

31     59. The method of claim 58, wherein the array is  
32     substantially planar.

1

2 60. The method of claim 58, wherein the array is  
3 hemispherical.

4

5 61. The method of any of claims 49-56, wherein a  
6 single electrode is provided, and is surrounded by a  
7 plane held at a constant potential.

8

9 62. The method of claim 61, wherein the electrode  
10 is circular.

11

12 63. The method of claim 61 or claim 62, wherein the  
13 plane is earthed.

14

15 64. The method of claim 62 or claim 63, wherein the  
16 frequency of alternating current voltage applied to  
17 the circular electrode is of a frequency having a  
18 period that is less than the time taken for light to  
19 pass over the diameter of the circular electrode.

20

21 65. The method of any of claims 49-64, wherein the  
22 voltages applied to adjacent first and second sets  
23 of electrodes in a planar array can be varied such  
24 that the at least one particle can be moved from the  
25 particle trapping region provided by the first set  
26 of electrodes to the particle trapping region  
27 provided by the second set of electrodes.

28

29 66. The method of claim 65, wherein at least one  
30 particle is moved from a first trapping region  
31 provided by a first set of electrodes to a second  
32 trapping region provided by a second set of

1 electrodes, wherein the voltages applied to the sets  
2 of electrodes is changed from an initial, to an  
3 intermediate and then to a final configuration, and  
4 wherein;

5 in an initial configuration, a first set of  
6 electrodes is biased to a holding voltage to form a  
7 first particle trapping region to trap at least one  
8 particle therein, and an adjacent second set of  
9 electrodes is biased to zero volts;

10 in an intermediate configuration, both sets of  
11 electrodes are biased to the holding voltage to form  
12 a merged particle trapping region that traps the at  
13 least one particle;

14 in a final configuration, the first set of  
15 electrodes is biased to zero volts, and the second  
16 set of electrodes is biased to the holding voltage  
17 to form a second particle trapping region, that  
18 traps the at least one particle.

19  
20 67. The method of claim 66, wherein the process of  
21 moving at least one particle from a first trapping  
22 region provided by a first set of electrodes to a  
23 second trapping region provided by a second set of  
24 electrodes is repeatable to move the at least one  
25 particle along a chosen path on the planar array.

26  
27 68. The method of claim 67, wherein the planar  
28 array is formed using printed circuit board,  
29 lithographic, or focussed ion beam technology.

30  
31 69. The method of any of claims 49-64, wherein a  
32 series of electrodes are provided, the voltages

1 applied to which are controllable such that the at  
2 least one particle can be moved from a first  
3 particle trapping region to a second particle  
4 trapping region, wherein the first trapping region  
5 is larger than the second trapping region.

6

7 70. The method of claim 69, wherein the voltages  
8 applied to the electrodes are controllable such that  
9 the at least one particle can be moved between a  
10 plurality of successively smaller trapping regions.

11

12 71. The method of claim 69 or claim 70, wherein the  
13 series of electrodes comprises a plurality of  
14 concentrically arranged circular electrodes.

15

16 72. The method of any of claims 69-71, wherein, in  
17 an initial state, every electrode has a combination  
18 of alternating current and direct current voltages  
19 applied such that at least one particle is trapped  
20 in a first trapping region;

21 the voltage applied to the outer electrode is  
22 changed such that, in an intermediate state, the at  
23 least one particle is trapped in a first  
24 intermediate trapping region provided by the  
25 remaining inner electrodes; and

26 the voltage applied to the electrode adjacent  
27 to the outer electrode is changed such that in a  
28 final state, the at least one particle is trapped in  
29 a second trapping region provided by the innermost  
30 electrode.

31

1     73. The method of claim 72, wherein, in the  
2     transitions from the initial to intermediate and the  
3     intermediate to final states, the outer and adjacent  
4     electrodes respectively are set to zero volts.

5  
6     74. The method of claim 72 or claim 73, wherein a  
7     plurality of electrodes each provide a further  
8     intermediate trapping region, such that, between the  
9     initial state and the final state, the at least one  
10    particle passes through a plurality of intermediate  
11    states, being trapped in successively smaller  
12    intermediate trapping regions.

13  
14    75. The method of any of claims 69-71, wherein, in  
15    an initial state, an outermost electrode has a first  
16    combination of alternating current and direct  
17    current voltages applied, and a background voltage  
18    is applied to the remaining electrodes such that, in  
19    an initial state, at least one particle is trapped  
20    in a first trapping region;

21       the electrode adjacent to the outer electrode  
22    is set to the first combination of voltages and the  
23    background voltage is applied to the outer electrode  
24    such that, in an intermediate state, the at least  
25    one particle is trapped in a first intermediate  
26    trapping region; and

27       the innermost electrode is set to the first  
28    combination of voltages and the background voltage  
29    is applied to the adjacent electrode such that, in a  
30    final state, the at least one particle is trapped in  
31    a second trapping region.

32

1 76. The method of claim 75, wherein the background  
2 voltage is zero volts.

3

4 77. The method of claim 75 or claim 76, wherein a  
5 plurality of electrodes is provided such that,  
6 between the initial state and the final state, the  
7 at least one particle passes through a plurality of  
8 intermediate states, being trapped in successively  
9 smaller intermediate trapping regions.

10

11 78. The method of any of claims 71-77, wherein the  
12 innermost electrode is provided with an aperture;  
13 and

14 when the at least one particle is in the final  
15 state, a voltage is applied to the aperture such  
16 that the at least one particle is urged through the  
17 aperture.

18

19 79. The method claim 78, wherein each side of the  
20 aperture is differentially pumped so that a gas  
21 passing through the aperture undergoes a supersonic  
22 expansion, so as to cool the particles that are  
23 urged through the aperture.

24

25 80. The method of any of claims 49-79, wherein the  
26 voltages applied to an electrode are such that one  
27 type of charged particle can be distinguished from  
28 another.

29

30 81. The method of claim 80, wherein different types  
31 of charged particle are trapped at different

1 distances perpendicularly from the surface of the  
2 electrode.

3

4 82. The method of claim 81, wherein the distance is  
5 dependent on the charge and/or mass of the charged  
6 particle.

7

8 83. The method of claim 82, wherein a first type of  
9 charged particle is trapped at a first perpendicular  
10 distance from the electrode, and a second type of  
11 charged particle is trapped at a second  
12 perpendicular distance from the electrode, wherein  
13 the mass of the first charged particle is greater  
14 than the mass of the second charged particle, and  
15 the second perpendicular distance is greater than  
16 the first perpendicular distance.

17

18 84. The method of claim 83, wherein at least one  
19 particle trapped at the second perpendicular  
20 distance is subject to the potential formed by a  
21 voltage sequence applied to a second set of  
22 electrodes.

23

24 85. The method of claim 84, wherein the voltage  
25 sequence applied to the second set of electrodes is  
26 such as to transport said at least one particle from  
27 one trapping region to another along a predetermined  
28 path.

29

30 86. The method of claim 84 or claim 85, wherein the  
31 dimensions of the second set of electrodes are of a

1 much larger scale than the dimensions of the trap  
2 electrode.

3

4 87. The method of any of claims 80-86, wherein an  
5 aperture is provided on an electrode such that the  
6 type of particle that is closest to the surface of  
7 the electrode can pass through the aperture.

8

9 88. The method of claim 87, wherein each side of  
10 the aperture is differentially pumped so that a gas  
11 passing through the aperture undergoes a supersonic  
12 expansion, so as to cool the particles that are  
13 urged through the aperture.

14

15 89. The method of any of claims 49-88, wherein the  
16 voltages applied to an electrode can be changed such  
17 that a trapped particle moves in a direction  
18 perpendicular to the plane of the electrode.

19

20 90. The method of claim 89, wherein at least one  
21 trapped particle can be lowered to a region where it  
22 will interact with at least one other particle; and  
23 the particles that result from the interaction  
24 can then be raised up again, together with particles  
25 that have not interacted.

26

27 91. The method of claim 89 or claim 90, wherein the  
28 electrode is formed with an aperture and the applied  
29 voltage can be changed to bring a particle close to  
30 the aperture; and

31 a voltage is applied to the aperture such that  
32 the particle is urged through the aperture.



1

2 92. The method of claim 91, wherein each side of  
3 the aperture is differentially pumped so that a gas  
4 passing through the aperture undergoes a supersonic  
5 expansion, so as to cool the particles that are  
6 urged through the aperture.

7

8 93. The method of any of claims 89-92, wherein an  
9 array of electrodes is provided, the voltages  
10 applied to which trap a first type of particle which  
11 can interact with a second type of particle, to form  
12 a reactant particle which falls to the bottom of a  
13 trap and is swept away through an extraction hole.

14

15 94. The method of claim 93, wherein the array of  
16 electrodes further comprises at least one aperture  
17 for the extraction of trapped particles.

18

19 95. The method of claim 94, wherein each electrode  
20 comprises one aperture.

21

22 96. The method of claim 95, wherein the reactant  
23 particle is accelerated through a potential and  
24 detected so that the position of the original first  
25 type of particle can be detected.

26